**UNIVERSITÀ DEGLI STUDI DI GENOVA**
**AREA RICERCA, TRASFERIMENTO TECNOLOGICO E TERZA MISSIONE**
**SERVIZIO RICERCA**
**SETTORE RICERCA NAZIONALE**

IL RETTORE

Vista la Legge 9 maggio 1989, n. 168 - Istituzione del Ministero dell'Università e della ricerca scientifica e tecnologica e ss.mm.ii;

Visto lo Statuto dell'Università degli Studi di Genova;

Visto il Regolamento Generale di Ateneo;

Visto il Regolamento di Ateneo per l'Amministrazione, la Finanza e la Contabilità;

VISTA la legge 7 agosto 1990, n. 241 recante "Nuove norme in materia di procedimento amministrativo e di diritto di accesso ai documenti amministrativi" pubblicata sulla Gazzetta Ufficiale n. 192 del 18/08/1990 e s.m.i.;

VISTO il Decreto del Presidente della Repubblica 28 dicembre 2000, n. 445 (Disposizioni legislative in materia di documentazione amministrativa) e s.m.i.;

VISTO il Decreto Direttoriale MUR n. 341 del 15/03/2022 di emanazione di un Avviso pubblico per la presentazione di Proposte di intervento per la creazione di "Partenariati estesi alle università, ai centri di ricerca, alle aziende per il finanziamento di progetti di ricerca di base" nell'ambito del Piano Nazionale di Ripresa e Resilienza, Missione 4 "Istruzione e ricerca" – Componente 2 "Dalla ricerca all'impresa" – Investimento 1.3, finanziato dall'Unione europea – NextGenerationEU";

VISTO il Decreto Direttoriale MUR n. 1561 dell'11 ottobre 2022 Codice identificativo PE00000021, Acronimo NEST, Titolo "Extended Partnership Network 4 Energy Sustainable Transiton" (CUP D33C22001330002) registrato alla Corte dei Conti il 04/11/2022 con prot. n. 2784 e relativi allegati;

CONSIDERATO che l'Università degli Studi di Genova è leader dello Spoke 4, dal titolo "Clean Hydrogen and Final Uses";

CONSIDERATO che gli Spoke possono emanare - nell'ambito dei limiti e con le modalità previste dall'Avviso - "bandi a cascata" finalizzati alla concessione di finanziamenti a soggetti esterni per attività coerenti con il progetto approvato;

VISTA la delibera della seduta del 27 settembre 2023 con cui il Consiglio di Amministrazione dell'Università degli Studi di Genova ha approvato il modello del "Bando a Cascata" per Organismi di Ricerca;

VISTO il Decreto del Direttore Generale n. 5418 del 14 novembre 2023 di nomina del Responsabile del Procedimento;

VISTO il Decreto del Rettore n. 366 del 24 gennaio 2024 di emanazione del Bando a cascata per il

finanziamento di proposte di intervento per attività di ricerca svolte da Organismi di Ricerca nell'ambito del Programma di ricerca "Extended Partnership Network 4 Energy Sustainable Transition – NEST" PE00000021 - SPOKE N. 4 - CUP D33C22001330002 di cui al Decreto direttoriale n. 1561 del 11 ottobre 2022, registrato dalla Corte dei Conti il 04/11/2022 n. 2784;

CONSIDERATO che alla data di scadenza per la presentazione delle proposte progettuali, fissata entro e non oltre il giorno 29 febbraio 2024, per la **Tematica G - Hydrogen hybrid propulsion system for special vehicles** era pervenuta a mezzo PEC all'indirizzo air3@pec.unige.it la seguente proposta:

**PROPONENTE: Università degli Studi di Napoli Parthenope - Prot. 15681 del 29.02.2024**
**TITOLO PROPOSTA: HyPOTT – Hydrogen hybrid POwer unit for a 4x2 Terminal Tractor**

TENUTO CONTO che con D.D. 1264 del 18 marzo 2024 la Responsabile del procedimento, Ing. Patrizia Cepollina, ha ritenuto ricevibile, ammissibile e conforme la proposta sopra citata;

CONSIDERATO che nel Bando è previsto che la valutazione di merito tecnico-scientifico dei progetti pervenuti sia affidata ad una Commissione composta da almeno tre esperti esterni al Partenariato, indipendenti e competenti dell'Area tematica dello Spoke;

VISTO il D.R. 1025 del 28 febbraio 2024 di emanazione dell'Avviso di manifestazione di interesse per la costituzione di un Albo di esperti indipendenti a supporto della valutazione di merito dei progetti PNRR presentati sui bandi a cascata del progetto NEST – "Extended Partnership Network 4 Energy Sustainable Transition";

VISTO il D.R. n. 1477 del 26 marzo 2024 che ha costituito l'Albo a supporto della valutazione dei progetti presentati in risposta al bando a cascata, emanato dall'Università degli Studi di Genova in qualità di Leader dello Spoke 4 del progetto NEST – CUP D33C22001330002, con D.R. n. 366 del 24/01/2024;

VISTO il D.R. n. 1549 del 28 marzo 2024 con cui è stata nominata la Commissione di valutazione delle proposte pervenute in risposta al bando a cascata indicato nelle premesse del presente decreto;

ACQUISITO il verbale della Commissione di Valutazione della seduta del 17 maggio 2024 (Prot. 43915 del 20 maggio 2024) per la Tematica G - Hydrogen hybrid propulsion system for special vehicles;

VISTO il verbale della riunione del 21 maggio 2024 (Prot. 45085 del 22 maggio 2024) di presa d'atto dei Verbali della Commissione di valutazione;

TENUTO CONTO che in data 27 maggio 2024 è stata inviata all'Università degli Studi di Napoli Parthenope la comunicazione Prot. 46787 in cui si rendevano noti gli esiti della procedura e si richiedeva la documentazione propedeutica all'adozione del provvedimento di ammissione del finanziamento;

TENUTO CONTO che la documentazione, ricevuta con nota Prot. 48658 del 30 maggio 2024 è stata ritenuta conforme a quanto previsto nel bando a cascata di cui al Decreto del Rettore n. 366 del 24 gennaio 2024, indicato nelle premesse del presente decreto,

DECRETA

ART. 1

L'ammissione a finanziamento del progetto "HyPOTT – Hydrogen hybrid POwer unit for a 4x2 Terminal Tractor" per la **Tematica G - Hydrogen hybrid propulsion system for special vehicles** con soggetto proponente Università degli Studi di Napoli Parthenope - come rappresentato negli Allegati B e C alla proposta presentata con domanda di partecipazione Prot. 15681 del 29 febbraio 2024

ART. 2

L'entità dell'agevolazione concessa, a fondo perduto, ammonta a 300.000 euro complessivi come rappresentati nell'allegato C alla proposta presentata con domanda di partecipazione Prot. 15681 del 29 febbraio 2024. L'agevolazione è pari al 100% dei costi di progetto trattandosi di attività di ricerca fondamentale per Organismi di Ricerca. L'agevolazione è concessa a valere sui fondi PNRR - Programma "NEST – Extended Partnership Network 4 Energy Sustainable Transition" Codice PE00000021 finanziato dalla Missione 4, Componente 2, Investimento 1.3, ai sensi del Decreto Direttoriale N. 1561 del 11 ottobre 2022, registrato dalla Corte dei Conti il 04/11/2022 n. 2784 iscritto al Bilancio di Ateneo sul progetto UGOV 100025-2022-LM-PNRR-PE_NEST_B_C_RICERCA_DIP- (CUP D33C22001330002);

ART. 3

Le attività di realizzazione del progetto, come indicate dettagliatamente negli Allegati B e C alla domanda di finanziamento, non potranno essere superiori a 12 mesi a decorrere dalla data di sottoscrizione del Contratto, salvo quanto previsto all'art. 6.3 del bando.
Le attività dovranno comunque essere concluse entro e non oltre il 31 agosto 2025, salvo proroghe del Programma di ricerca NEST concesse dal MUR, affinché siano rendicontate in tempo utile per consentire la chiusura del Programma di ricerca NEST il cui termine è attualmente previsto al 31 ottobre 2025.

ART. 4

Il presente atto sarà pubblicato sul sito UniGe https://unige.it/progetti-finanziati-dal-pnrr e sul sito https://fondazionenest.it - sezione Bandi.

Il documento informatico originale sottoscritto con firma digitale sarà conservato presso l'Area Ricerca, Trasferimento Tecnologico e Terza Missione.

IL RETTORE
Prof. Federico DELFINO
*(documento firmato digitalmente)*

Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | NEST

**ALLEGATO B**

PE00000021
"PNRR MUR - M4C2 – NEST - Extended Partnership Network 4 Energy Sustainable Transition"

SPOKE N. 4

CUP D33C22001330002

Research proposal

Topic addressed by the project:
**g - Hydrogen hybrid propulsion system for special vehicles**

Title:
# HyPOTT - Hydrogen hybrid POwer unit for a 4x2 Terminal Tractor

- Host Institution: University of Naples Parthenope
- PI: Elio Jannelli, co-PI: Giovanni Di Ilio
- Proposal duration in months: 12

- Name and qualification of the Principal Investigator (PI)
- Name and qualification of the co- Principal Investigator (PI)
- Name and qualification of the components the research team

| *ROLE IN THE PROJECT* | *NAME* | *SURNAME* | *INSTITUTION/ DEPARTMENT* | *QUALIFICATION* | *YOUNG (under 40 al 31.12.2023)* | *F/M* |
|---|---|---|---|---|---|---|
| Principal Investigator | *Elio* | *Jannelli* | *University of Naples Parthnope, Department of Engineering* | *Full Professor* | *NO* | *M* |
| co-Principal Investigator (PI) | *Giovanni* | *Di Ilio* | *University of Naples Parthnope, Department of Engineering* | *Assistant Professor* | *YES* | *M* |

**ABSTRACT**

The port-logistic sector plays a crucial role in the economic development of a country. In addition, given the current growth of port commercial traffic worldwide, it has a significant impact also in terms of quality of life, mainly in the environment nearby ports and on the surrounding coastal areas. Promoting innovation on efficiency and sustainability of ports is therefore a fundamental issue. This holds especially considering the increase of foreign trade cargo volumes, which have driven maritime ports into developing their capacities from all perspectives, and the European Commission's strategic vision for achieving a climate neutral economy by 2050.

The port environment is indeed a large ecosystem, made of complex infrastructures, variegate services and advanced equipment, which require a conspicuous energy demand, today inherently related to the release of a high amount of harmful emissions, due to the intensive use of fossil fuels. Within this context, the proposed action aims at facilitating a fast decarbonisation of the port logistic industry by applying hydrogen technologies, already used in other sectors, but not yet adopted in the port sector. In particular, this project aims to develop and assess a fuel cell/battery hybrid powertrain for a yard tractor, that is a special vehicle used in terminals to move heavy trailers within different areas. This particular vehicle has been selected as it is one of the most spread machinery used in port handling operations. Thus, the successful demonstration of a fuel cell electric configuration of this vehicle may be an effective driver for the introduction of hydrogen technologies into the port sector.

**RESEARCH PROPOSAL**
**Sections (a) and (b) should not exceed 4 pages. References do not count towards the page limits.**

**Section a. State-of-the-art and objectives**

The maritime transport sector is responsible for a significant share of $CO_2$ emissions, that is around the 2.5% of the total at global scale [1]. A significant portion of these emissions originates from ships during port stays and in-port operations. In fact, the port-logistic industry has a significant impact on the urban environment nearby ports and on the surrounding coastal areas. This is due to the use of large auxiliary power systems on ships operating during port stays, as well as to the employment of a number of fossil fuel powered road vehicles required for port operations, such as yard trucks, forklifts, container movers, and rubber-tired gantry cranes. Given the demanding and energy-intensive nature of their activities, these vehicles require substantial power and on-board energy storage to maintain all-day operations, characterized by diverse operating conditions and tasks. Port machinery, typically powered by diesel engines, emits significant amounts of particulate matter, nitrogen oxides, and volatile organic compounds, which degrade air quality and contribute to noise pollution. The pathway to achieve decarbonization and mitigation of energy use in ports involves therefore the adoption of alternative and cleaner technology solutions for the propulsion systems of such port vehicles. The redesign of these vehicles with a focus on environmental sustainability presents a promising yet challenging solution to accelerate decarbonization and energy use reduction in port areas. Among the various alternatives for powering such vehicles, hydrogen fuel cells (FCs) emerge as one of the most promising options, owing to their scalability, flexibility, and high efficiency, particularly when combined with energy storage devices like Li-ion batteries. In fact, hydrogen technologies are inherently clean, given that FCs operate through electrochemical reactions producing only water and heat as by-products. Additionally, fuel cells offer silent operation, a very appealing feature, especially in the context of a port environment.

Hybrid electric powertrains utilizing FCs have already been extensively explored for heavy-duty vehicle applications [2]. In particular, hydrogen fuel cells have attracted significant interest from ports worldwide, despite limited practical experience to date. Notably, the ports of San Pedro Bay (Long Beach and Los Angeles) have taken a leading role in fuel cell adoption through initiatives like the Zero Emission Cargo Transport II (ZECT II) project, which involved testing three drayage trucks using FCs, either as range extenders or primary power sources. The first hydrogen-fuelled vehicle for handling materials in ports has been recently developed within the EU project H2PORTS – "Implementing Fuel Cells and Hydrogen Technologies in Ports" [3] by *ATENA scarl - High Technology for Energy and Environment District*, along with its third party *uniParthenope*, whose members are the same of this proposal. The developed vehicle is a RoRo tractor, that is a heavy duty 4x4 vehicle used for carrying wheeled trailers from the terminal area to the inside of a cargo ship and vice-versa, according to standard Roll-on/Roll-off operations. In particular, in the H2PORTS project *uniParthenope* took care of the whole design process of the hybrid powertrain, while the assembling activities of the new components on-board of the vehicle was in charge of *Cantieri del Mediterraneo s.p.a.*.

By leveraging on the experience and knowledge acquired during the H2PORTS project and other past similar projects where fuel cell power units were developed and successfully demonstrated, this project aims to design and test a hybrid fuel cell/battery powertrain for a yard tractor used in port logistics, whose average power output falls within the targeted 10-30 kW range. The research unit of *uniParthenope* will carry out the design process of such a powertrain, starting from a careful data acquisition campaign on an original vehicle operating in port, to the final experimental demonstration, at lab scale, of the developed system. The activities will be supported by *Cantieri de Mediterraneo s.p.a.* and *HyTECS - Hydrogen Technologies and Energy Consulting Services*, that is a new-established spin-off of uniParthenope. Some of the members of *HyTECS* are indeed researchers of *uniParthenope* who were actively involved in the activity of the H2PORTS project with specific competences in the design of control systems and telemetry systems.

In particular, the considered yard tractor is a 4x2 heavy-duty vehicle, typically employed for moving trailers within different areas of the terminal hub of the port. Despite having a similar layout, this kind of vehicle differs from the RoRo tractor already developed by the research unit, in terms of duties and, as a consequence,

of energy and power requirements. The research unit of *uniParthenope* will tackle all the challenges related to the new specifications, by taking advantage of the common ground between the two vehicles, namely the RoRo and the Yard Tractor.
As a fundamental requirement, the hybrid powertrain of the Yard Tractor will be designed in a way to guarantee at least the same performance, in terms of driving range and operational capabilities, of the original vehicle, currently equipped with an internal combustion engine powered by fossil fuel. As a general approach, the hydrogen fuel cell will be sized to meet the average power demand of the vehicle, hence making hydrogen the main source of energy on-board; while the battery pack will be sized so to deal with the transient operations and to satisfy higher power demands. By this means, an overall downsizing of the whole powertrain will be achieved, thus allowing for an optimization of the powertrain architecture, both in terms of layout and operation. In order to fully exploit the potential of the hybrid system, appropriate control strategies will be developed, so to make the use of the energy stored on board as efficient as possible, depending on the particular operation carried out by the vehicle. In these regards, a charge sustaining approach will be followed. By this way, short refuelling times will be achieved, given that the battery pack is charged by the fuel cell only, during vehicle operation. Moreover, the definition of the optimal control strategy will necessarily take into account the aspects related to the useful life of the components, in order to preserve their correct functioning over time, and consequently reduce the costs related to maintenance.
In the near-term, converting this vehicle into a hydrogen configuration is expected to offer a more viable and economical solution with respect to fossil fuel alternatives. Therefore, this project aims at facilitating this process and boost the adoption of hydrogen as a fuel into the port sector, by the demonstration of a new clean and efficient technology for handling equipment.

**Section b. Methodology**
The growing need for a sustainable worldwide mobility is leading towards a paradigm shift in the automotive industry. Therefore, it is of paramount importance to develop new advanced clean technologies and, among the many solutions, promote the hydrogen economy. In this context, the focus of this project is on the development of a hybrid fuel cell electric powertrain for a yard tractor specifically designed for terminal operations inside the port environment. In particular, the duties of this vehicle consist in the transport of various goods within the port, between different operational areas.
To achieve its ambitious goal, the project will rely on a multidisciplinary approach which involves competence in several different fields, which will be exploited through a systematic analysis involving both numerical and experimental activities, and that is grounded on a modular design approach.
The basic idea behind the new powertrain of the vehicle is to design it in such a way that the peculiarities of its main components, i.e. fuel cell and battery pack, are fully exploited. Hence, the vehicle will be equipped with a moderately-sized battery, that has to accomplish the following tasks: i) provide power to the vehicle during transient operations and protect the fuel cell from fast load dynamics; ii) recover as much as kinetic energy as possible during braking events; iii) ensure an adequate all-electric range, in case of fuel cell faults. On the other hand, the fuel cell system of the vehicle will be sized on the average estimated power demand, in order to avoid the battery state of charge depletion under continuous vehicle operation. In fact, generally speaking, the average power demand is only a fraction of the peak power request experienced by the vehicle, therefore the fuel cell rated power can be eventually selected by considering the expected mean power request. This powertrain configuration allows to reduce the overall costs by downsizing both the fuel cell stack and the battery pack. Moreover, it allows for flexible use of the vehicle and redundancy, thus improving the reliability of the powertrain.
The powertrain design process will be carried out according to an iterative approach involving technology selection, mission profile identification, simulation of power unit configurations and control strategies, and optimization based on cost objectives. Specifically, this process will be deployed into three main phases: during the first phase, an in-depth knowledge of the typical duty cycles of the vehicle will be gathered by performing a detailed data acquisition campaign and analysis; the second phase will consist in identifying the technology for the components of the power unit (fuel cell, battery, electric motor, converters, etc.), that will be chosen

based on both economic and technical considerations; in a third phase, various power unit configurations and different control strategies will be proposed and simulated. Hence, modelling of hybrid vehicle powertrains will be set up and used to support the design and validate the performance of the vehicle against realistic mission profiles.
Once the design of the vehicle powertrain and of its energy management strategy will be achieved, the system will be prototyped and tested in lab environment. This phase will involve a comprehensive testing aimed at characterizing either each single component and their integration into the whole powertrain system. Focus will be devoted on comparing the hybrid power unit's performance against the conventional solution based on fossil fuelled internal combustion engine. Therefore, all powertrain systems and components will undergo rigorous lab testing to ensure compliance with design specifications, safety standards, and technical requirements.
The activities of this project are structured according to three main tasks. Below, a detailed description of the work is reported, task by task.

Description of work

**Task 1 - Design**
The design process of the new fuel cell/battery hybrid powertrain of the vehicle starts with the definition of technical and functional requirements, by considering actual mission profiles. Therefore, at the beginning of the project, a careful data acquisition campaign will be carried out by setting up a telemetry system based on CAN-bus communication and installing it on-board of an existing yard tractor, operating in the port of Genova, after the approval of port authorities. The telemetry system will be developed by *uniParthenope* in a synergic collaboration with *HyTECS*. As anticipated above, the members of *HyTECS* conducted a similar activity during the development of the RoRo tractor in the H2PORTS project and, for this reason, this activity will benefit from their past experience. Specifically, the telemetry system will enable real-time monitoring and data storage of all key parameters of the vehicle, such as engine speed, torque, fuel consumption, exhaust emissions, and other. These information will be instrumental to understand the powertrain requirements and develop an optimal hybrid system layout.
Data will be then used to simulate the powertrain operations into a numerical framework, and to derive some crucial insights related for instance to the kinetic energy recovery capabilities of the newly designed system. To this aim, models of vehicle longitudinal dynamics will be developed and used along with backward and forward vehicle simulators, in order to model, design and optimize the layout of a fuel cell/battery hybrid powertrain. As a main output from this analysis, each of the main components, i.e. fuel cell, battery pack, electric motor, will be sized and selected from available products in the market.
A suitable energy management strategy will be then developed during this stage. This will be designed to: i) minimize hydrogen consumption, ii) preserve the life of each powertrain components, iii) ensure the correct operation and comply with the dynamics characteristics of each powertrain component. To this aim, several rule-based energy control strategies based on a feedback control on the battery state of charge will be implemented and tested. As a result, the energy management strategy better exploiting the features of the hybrid powertrain will be retrieved, for the online implementation on-board of the vehicle.
Once the final configuration for the power unit will be fully defined, the aspects related to the thermal management of the its components will be tackled by ad-hoc analysis. Particular attention will be given to the thermal management of the battery pack, in order to avoid risks associated to thermal runaway. The integration of the various components (fuel cells and batteries) will be made through power converters and will be guaranteed by a control unit that will be able to interface with all components of the power unit. Finally, the design of electrical and mechanical auxiliary systems will be carried out, including hydrogen piping and wiring, by considering the actual space availability on-board of the real vehicle.

**Task 2 – Assembling**
After the design of the power unit and of its auxiliary systems, a prototyping activity will be carried out. Thus, first the procurement of components will be conducted: the choice of using commercially available

components is made in order to provide a fast and effective prototyping of the system, in line with the scope of this project. The integration and assembling of the power unit will be conducted by *uniParthenope* along with *Cantieri del Mediterraneo s.p.a.*. In fact, *Cantieri del Mediterraneo s.p.a.* has already gathered a unique experience and know-how during the development of the above mentioned RoRo tractor, in the context of the EU project H2PORTS and, therefore, its support would be instrumental. The system to be assembled will include also hydrogen piping and electric routing, as to demonstrate a fully operational system. The power unit will be then installed at the test bench, where testing will be conducted at both component and system level.

**Task 3 – Testing**

The developed fuel cell/battery hybrid power unit for the yard tractor will be extensively tested in lab environment, in order to validate it and fully characterize its performance. In particular, several preliminary tests will be conducted by using synthetic duty cycles, ad-hoc defined to investigate on the performance of individual components under a wide range of operating conditions, in order to assess their dynamic response, their integration and the effectiveness of the thermal management system. Afterwards, tests will be performed by using the real duty cycles previously acquired from the on-field campaign, in such a way to gather the most valuable information about the dynamic behaviour of the whole prototype under real operation conditions. These activities will be supported by *HyTECS*, in particular those related to the definition of control systems, needed to make the integration of the power unit on the test bench fully operational.

During this last stage of the project, an exhaustive assessment for the proposed energy management strategy will be performed, eventually leading to its improvement, before the future integration of the power unit on-board of the vehicle. Care will be taken also to compare both the technical performance and the economic viability of the newly developed powertrain against the original one: to this aim, several key performance indicators will be defined and evaluated, to provide a qualitative and quantitative comparison between the two solutions.

**REFERENCES**

[1] European Commission. Annual Report on CO2 Emissions from Maritime Transport, SWD2020 82; 2019.

[2] D.A. Cullen et al., New roads and challenges for fuel cells in heavy-duty transportation, Nature Energy 6, 462-474 (2021), https://doi.org/10.1038/s41560-021-00775-z

[3] https://h2ports.eu/ (accessed February 2024)

**Section c. Available instrumentations and resources**

| Name of infrastructure | Short description |
|---|---|
| **HYBRID POWER LAB** | *Transient testing of FC hybrid electric power units up to 160 kW of power output.*<br>- AVL Puma Data Acquisition System;<br>- AVL Load Unit System (Dynodur);<br>- AVL Blow By and oil consumption meter;<br>- AVL BTE for testing and emulating battery Pack and fuel cell devices (E-STORAGE HV 160kW@1000V –max 250A) |
| **FUEL CELL LAB** | *Testing and characterization of fuel cells.*<br>- Single Cell PEM Test benches<br>- Gas chromatography unit<br>- 2kW PEM stack Test bench.<br>- 5 kW SOFC Test Bench<br>- Single Cell SOFC and SOEC Test Benches<br>- Single Cell MCFC Test benches<br>- MFC &MEC Testing equipment |
| **METAL HYDRIDE LAB** | *Testing and characterization of hydrogen storage systems with metal hydrides.*<br>- Glovebox<br>- Electrolyser<br>- Suction hoods |
| **PROTOTYPING LAB** | *Numerical modelling and analysis, CAD environment, prototyping of components.*<br>- Workstations<br>- 3D Printers |

## Section d. GANTT diagram

| | | Timeline | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
| 1 | DESIGN | | | | | | | | | | | | |
| | Preliminary analysis, definition of requirements and control strategies | | | | | | | | | | | | |
| | Power Unit Design | | | | | | | | | | | | |
| MS1 | END OF Design | | | | | | x | | | | | | |
| 2 | ASSEMBLING | | | | | | | | | | | | |
| | Power Unit Components procurement | | | | | | | | | | | | |
| | Power Unit Assembling | | | | | | | | | | | | |
| MS2 | END OF Assembling | | | | | | | | | x | | | |
| 3 | TESTING | | | | | | | | | | | | |
| | Power Unit Development & Testing | | | | | | | | | | | | |
| | Cost Benefit Analyis e Business case | | | | | | | | | | | | |
| MS3 | END OF Testing | | | | | | | | | | | | x |

## Section e. Milestones, Deliverables and KPI

MILESTONES

| # | Title | Month |
|---|---|---|
| M1 | End of design | M6 |
| M2 | End of assembling | M9 |
| M3 | End of testing | M12 |

DELIVERABLES

| # | Title | Month |
|---|---|---|
| D1 | Report on power unit design | M6 |
| D2 | Final report | M12 |

KPIs

- System nominal efficiency [%]
- Fuel/energy consumption per working shift [kWh]
- Hot-idle ramp time [s]
- Cold-start ramp time [s]
- Power unit capital cost [€/kW]

## Annexes: Curriculum vitae research team

**Appendice dell'Allegato B**

**Curriculum vitae PI**

**PERSONAL INFORMATION**

Family name, First name: JANNELLI ELIO

Researcher unique identifier(s): https://orcid.org/0000-0002-8605-9905

Date of birth:

Nationality:

URL for web site: https://www.uniparthenope.it/Portale-Ateneo/organigramma/1910

- **EDUCATION**

| | |
|---|---|
| 1987 | PhD in Fluid Machinery and Power Plants<br>University of L'Aquila, Italy |
| 1982 | Master in Energy Management<br>University of Naples Federico II, Italy |
| 1981 | MSc in Mechanical Engineering<br>University of Naples Federico II, Italy |

- **CURRENT POSITION(S)**

| | |
|---|---|
| 2001 – today | Full Professor – Energy Systems<br>Dept. of Engineering, University of Naples "Parthenope", Italy |
| 2016 – today | CEO<br>ATENA scarl – Distretto Alta Tecnologia Energia e Ambiente, Italy |

- **PREVIOUS POSITIONS/WORK EXPERIENCE**

| | |
|---|---|
| 2019 – 2022 | Member of National Committee of Guarantors for Research<br>Italian Ministry of Research |
| 2022 – 2022 | Member of the Technical board for the elaboration of the Italian Strategy of Hydrogen Research - SIRI<br>Italian Ministry of Research |
| 2019 – 2021 | Member of the Technical board for the elaboration of the National Research Program - PNR 2021/2027<br>Italian Ministry of Research |
| 2008 – today | Director of the Energy Systems Lab<br>University of Naples "Parthenope" |
| 2008 – today | Coordinator of the Advanced Energy Systems Group<br>University of Naples "Parthenope" |
| 2014 – 2016 | President of Scientific Committee<br>ATENA scarl – Distretto Alta Tecnologia Energia e Ambiente |
| 1996 – 2008 | Coordinator of the Fuel Cell Research Team<br>University of Cassino |
| 1996 – 2008 | Director of the Fluid Machinery and Energy Laboratory |

University of Cassino

- **FELLOWSHIPS AND AWARDS**

1999 Best Paper Award in the Track on Simulation, Virtual Reality and Automotive supercomputing for scientific paper "Numerical Simulation of Four Cylinder, 16 Valve, Spark-Ignition Engine"

1999 ATI/ESSO Award for Master Degree Thesis: "Performance analysis of Intercooled and Reheat High Pressure Gas Turbine cycles" – Candidate: M. Minutillo

1999 ATI/ESSO Award for Master Degree Thesis "Analisi, simulazione ed ottimizzazione di un impianto di produzione di energia elettrica da fonti rinnovabili" – Candidate: M. Cusano

2004 ATI/ESSO Award for Ph.D. Thesis "Multidimensional Modeling of Premixed Turbulent Combustion: Models and Experimental Test of a Small Spark-Ignition Engine" – candidate: M. Minutillo

2005 ATI/ESSO Award for Master Degree Thesis "Numerical modeling of a spark-ignition engine fueling with premixed lean air-gasoline-hydrogen mixtures." – candidate: E. Ciacciarelli

- **SUPERVISION OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS**

2008 – today 30 Postdocs/ 25 PhD/ 30 Master Students
University of Naples "Parthenope", Italy

1988 – 2008 5 Postdocs/ 5 PhD/ 50 Master Students
University of Cassino, Italy

- **ORGANISATION OF SCIENTIFIC MEETINGS**

2017 – today Member of the Scientific and Organizing Committee of the European Fuel Cell and Hydrogen Piero Lunghi Conference

- **INSTITUTIONAL RESPONSIBILITIES**

2017 – 2020 Rector's Delegate for Research
University of Naples "Parthenope"

2014 – 2017 President of the Joint Evaluation of Teaching at Engineering Department
University of Naples "Parthenope"

2013 – 2011 Director of the PhD course in Energy Science and Engineering (ESE)
University of Naples "Parthenope"

2011 – 2014 Director of the PhD course in Industrial Engineering
University of Naples "Parthenope"

2008 – 2014 President of the Education Committee in Management Engineering (Master Degree Courses)
University of Naples "Parthenope"

2003 – 2004 President of the Selection Committee of the qualifying evaluation for the profession of engineer
University of Cassino

2002 – 2008 Member of the Joint Evaluation of Teaching at Faculty of Engineering
University of Cassino

2001 – 2002 Member of the Education Committee of the Master and Degree in Mechanical Engineering

University of Cassino

2000 – 2006 Member of the Ph.D. Committee in Civil and Industrial Engineering
University of Cassino

1998 – 1999 Responsible for Design, testing and commissioning of the experimental facilities at the Research Laboratory "Energy Systems"
University of Cassino

1988 – 1993 Member of Academic Committee for the management of the Department of Mechanical Engineering
University of Cassino

- **REVIEWING ACTIVITIES**

Reviewer, Journal: Energy – ELSEVIER
Reviewer, Journal: Applied Energy – ELSEVIER
Reviewer, Journal: Energy Procedia – ELSEVIER
Reviewer, Proceeding of the European Fuel Cell and Hydrogen Piero Lunghi Conference

- **MAJOR COLLABORATIONS/COMPLETED R&I PROJECTS**

2024 Visiting Professor
University of California, Irvine, US

2022 – 2023 H2RESTORE Sviluppo di un modulo integrato di accumulo di energia elettrica da fonte rinnovabile con tecnologie Innovative a idrogeno
funded by GRADED & Regione Campania

2022 – 2023 MHYMOST – Metal Hydrides-based hYdrogen storage for MObile and STationary applications
funded by Cantieri del Mediterraneo & Regione Campania

2022 – 2023 BEST Shelter modulari per la realizzazione di sistemi di stoccaggio e accumulo lithium-based
funded by MECOSER Sistemi & Regione Campania

2018 – 2020 "HyLIVE - Hydrogen Light Innovative Vehicles"
funded by Regione Campania

2018 – 2019 "ATENA FUTURE TECHNOLOGY"
funded by Regione Campania

2016 – 2018 Innovative technologies for fast ships performance detection and control
funded by Italian Ministry of Economic Development

2015 – 2016 ET-NET - Emerging energy Technologies for International NETworks
funded by Regione Campania

2013 – 2015 MITO - Multimedia Information for Territorial Objects"
funded by Italian Ministry of Education, University and Research

2011 – 2017 "Smart Generation"
funded by Italian Ministry of Education, University and Research

2011 – 2016 "Fuel Cell Lab"
funded by Italian Ministry of Education, University and Research

2011 – 2012 "Preliminary study for Fuel Cell APU application on MALE - UAV"
funded by CIRA - Italian Aerospace Research Centre

2011 – 2012 "Preliminary study for the selection and sizing of a hybrid propulsion system for UAS"
funded by CIRA - Italian Aerospace Research Centre

2007 – 2008 "Development of a regenerative energy system for HALE-UAV"

funded by CIRA - Italian Aerospace Research Centre

2007 – 2008 "Technical and economic evaluation of a waste treatment plant integrated with a CHP plant"
funded by Italian Ministry of Agriculture and Forestry

2007 – 2008 "Development of micro-CHP systems with fuel cells fed by hydrogen generators"
by the National Research Council and Italian Ministry of Economic Development.

2006 – 2007 "Development of an innovative prototype for dispersed generation of electricity and heat with high efficiency and low environmental impact, based on fuel cells powered by hydrogen produced from natural gas"
funded by Coelmo spa and Italian Ministry of Economic Development

2004 – 2005 "Development of mobile microgenerators powered by PEM fuel cell for low power application"
funded by Coelmo spa and Regione Campania

2001 – 2002 "Environmental Impact of 800 MW combined cycle power plant – site of Paduli"
funded by Ansaldo Energia and General Construction

2001 – 2002 "Assets estimation of 12Mwe cogeneration plant – Anagni site"
funded by Videocolor (Thomson Group) and Cogetherm (EDF Group)

1996 – 1998 "Reversible energy storage systems"
funded by University of Cassino

1997 – 2000 "Fuel saving and emissions reduction by use of non-conventional fuels in internal combustion engines"
funded by Regione Lazio

1991 – 1993 Research and Innovation Project: "Optimization of CHP Energy Systems"
funded by ENEL - Thermal Research Centre of Pisa.

***Appendix: All current grants and on-going and submitted grant applications <u>of the PI</u> (Funding ID)***

*<u>Mandatory information</u> (does not count towards page limits)*

**Current grants (Please indicate "No funding" when applicable):**

| *Project Title* | *Funding source* | *Amount (Euros)* | *Period* | *Role of the PI* | *Relation to current proposal* |
|---|---|---|---|---|---|
| ALRIGH2T – Airport Level DemonstRatIon of Ground refuelling of liquid Hydrogen for AviaTion | European Commission (Horizon-Cl5-2023-D5-01) | 355.000 (Parthenope 55.000) | 2024-2027 | Task leader & Atena Research unit coordinator | Power unit testing for Airport Ground Vehicles |
| H2EXCELLENCE – Fuels Cells and Green Hydrogen Centers of Vocational Excellence towards affordable, secure and sustainable energy for Europe | European Commission Erasmus-Edu-2022 | 227.589 | 2023-2027 | Task Leader & Atena Research unit coordinator | Hydrogen & Fuel Cells education & dissemination |
| PROTOSTACK - Tubular proton conducting ceramic stacks for pressurized hydrogen production | European European Clean Hydrogen Partnership | 150.000 (Parthenope 37.500) | 2023-2025 | Task Leader & Atena Research unit coordinator | High Efficiency green hydrogen generation |
| FuelSOME – Multifuel SOFC system with Maritime Energy vectors | European Climate, Infrastructure And Environment Executive Agency (Cinea) | 150.000 (Parthenope 21.250) | 2022-2025 | Task Leader & Atena Research unit coordinator | Hydrogen Use in maritime sector |
| e-SHyIPS - Ecosystemic knowledge in Standards for Hydrogen Implementation on Passenger Ship | European Clean Hydrogen Partnership | 130.625 (Partenope 35.000) | 2021 - 2024 | Task Leader & Atena Research unit coordinator | Hydrogen Use in maritime sector & modeling of power unit for ships |
| H2PORTS - Implementing Fuel Cells and Hydrogen Technologies in Ports | European Clean Hydrogen Partnership | 676.900 (Parthenope 75.000) | 2019 - 2024 | WP – Leader & Atena Research unit coordinator | First Hydrogen RoRo Tractor in the world |
| Accordo di Programma Ricerca di Sistema – Progetto integrato idrogeno | ENEA – RSE su fondi MASE | 220.000 | 2022-2024 | Principal Investigator | Hydrogen Energy storage Systems |
| HyReFi – Modeling and Optimization of sustainable Hydrogen Refuelling Infrastructure | MUR – Ministero Università e Ricerca – Bando PRIN 2022 PNRR | 165.544 | 2023-2025 | Principal Investigator | Modeling & optimization of Innovative HRS |

**Appendice dell'Allegato B**

**Curriculum vitae CO-PI**

**PERSONAL INFORMATION**

Family name, First name: DI ILIO GIOVANNI

Researcher unique identifier(s): https://orcid.org/0000-0001-8056-8736

Date of birth:

Nationality:

URL for web site: https://www.uniparthenope.it/Portale-Ateneo/organigramma/1428

- **EDUCATION**

2017 PhD – Energy Science and Engineering
University of Naples "Parthenope", Italy
Supervisor: Prof. Gino Bella

2014 MSc in Mechanical Engineering
University of Rome "Tor Vergata", Italy

2013 MSc in Mechanical Engineering
Polytechnic Institute of New York University, US

2010 BSc in Mechanical Engineering
University of L'Aquila, Italy

- **CURRENT POSITION**

2023 – today Researcher (art. 24 c.3-b L.240/10)
Dept. of Engineering, University of Naples "Parthenope", Italy

- **PREVIOUS POSITIONS**

2020 – 2023 Researcher (art. 24 c.3-a L.240/10)
Dept. of Engineering, University of Naples "Parthenope", Italy

2017 – 2020 Post-Doc
Dept. of Engineering, University of Rome "Niccolò Cusano", Italy

- **FELLOWSHIPS AND AWARDS**

2023 Best Researcher of the Year
Young Scientist Award competition, by Hydrogen Europe Research

2012 Graduate Innovation Fellowship
Merit-based scholarship awarded based on academic achievements, offered by Polytechnic Institute of New York University

- **ORGANISATION OF SCIENTIFIC MEETINGS**

2024 Member of the Scientific Committe and Session Organizer
4th Conference on Sustainable Mobility (CSM2024), Italy
2022 Member of the Scientific Committe and Session Organizer
3rd Conference on Sustainable Mobility (CSM2022), Italy
2021 Member of the Organizing Committe
9th European Fuel Cells and Hydrogen Piero Lunghi Conference (EFC201), (online)
2020 Member of the Organizing Committe
29th International Conference on Discrete Simulation of Fluid Dynamics DSFD2020, (online)

- **INSTITUTIONAL RESPONSIBILITIES**

2021 – today Member of the Scientific Board, PhD program "Energy Science and Engineering"
Dept. of Engineering, University of Naples "Parthenope"
2020 – today Member of the Committee for Internationalization
Dept. of Engineering, University of Naples "Parthenope"

- **REVIEWING ACTIVITIES**

2022 – today Scientific Advisory Board
Conference on Sustainable Mobility (CSM)
2021 – today Editorial Board Member
Journal of Computational Science – ELSEVIER
2020 – today Guest Editor for International Journals:
- Sustainable Energy Technologies and Assessments – ELSEVIER
- Processes – MDPI
- Sustainability – MDPI
- Journal of Computational Science – ELSEVIER
- Philosophical Transaction of the Royal Society – The Royal Society
- Applied Sciences – MDPI

2016 – today Reviewer of more than 30 International Journals, among which:
- Applied Energy
- International Journal of Hydrogen Energy
- Cleaner Energy Systems
- Journal of Cleaner Production
- Energy Conversion and Management
- Energies
- International Journal of Engine Research

2021 Scientific Evaluator
For the Best Master Degree Thesis award, by Society of Automotive Engineers - Naples Section (SAENA)

- **MAJOR COLLABORATIONS/COMLPETED PROJECTS**

2022 – 2023 H2RESTORE Sviluppo di un modulo integrato di accumulo di energia elettrica da fonte rinnovabile con tecnologie Innovative a idrogeno

funded by GRADED & Regione Campania

2022 – 2023 MHYMOST – Metal Hydrides-based hYdrogen storage for MObile and STationary applications
funded by Cantieri del Mediterraneo & Regione Campania

2022 – 2023 BEST Shelter modulari per la realizzazione di sistemi di stoccaggio e accumulo lithium-based
funded by MECOSER Sistemi & Regione Campania

2020 – 2020 HyLIVE - Hydrogen Light Innovative Vehicles
funded by Regione Campania

2018 – 2019 PAINT-IT – A new environment-friendly manufacturing approach for marine antifouling coating
funded by EU LIFE Program

2017 – 2018 NEMESIS – Combined numerical and experimental methodology for fluid structure interaction in free surface flows under impulsive loading
funded by Italian Ministry of University and Research, PRIN 2015

2017 – 2017 ATRE – Eco-sustainable thermal energy storage system for residential applications
funded by Italian Ministry of Economic Development, co-financed by the EU

2017 Academic Guest
Swiss Federal Institute of Technology (ETH), Aerothermochemistry and Combustion Systems Laboratory, Zurich, Swiss

2018 Academic Guest
Silesian University of Technology, Institute of Thermal Technology, Gliwice, Poland

2014 – 2014 Hi-Quad: development of an innovative four-wheeled hybrid vehicle for urban mobility
funded by Italian Ministry of Economic Development

***Appendix: All current grants and on-going and submitted grant applications <u>of the Co-PI</u> (Funding ID)***

*<u>Mandatory information</u> (does not count towards page limits)*

**Current grants (Please indicate "No funding" when applicable):**

| *Project Title* | *Funding source* | *Amount (Euros)* | *Period* | *Role of the CoPI* | *Relation to current proposal* |
|---|---|---|---|---|---|
| ALRIGH2T – Airport Level DemonstRatIon of Ground refuelling of liquid Hydrogen for AviaTion | European Commission (Horizon-Cl5-2023-D5-01) | 355.000 (Parthenope 55.000) | 2024-2027 | Member of the Research Unit of Atena | Power unit testing for Airport Ground Vehicles |
| H2EXCELLENCE – Fuels Cells and Green Hydrogen Centers of Vocational Excellence towards affordable, secure and sustainable energy for Europe | European Commission Erasmus-Edu-2022 | 227.589 | 2023-2027 | Member of the Research Unit of Atena | Hydrogen & Fuel Cells education & dissemination |
| PROTOSTACK - Tubular proton conducting ceramic stacks for pressurized hydrogen production | European European Clean Hydrogen Partnership | 150.000 (Parthenope 37.500) | 2023-2025 | uniParthenope Research Unit coordinator | High Efficiency green hydrogen generation |
| FuelSOME – Multifuel SOFC system with Maritime Energy vectors | European Climate, Infrastructure And Environment Executive Agency (Cinea) | 150.000 (Parthenope 21.250) | 2022-2025 | Member of the Research Unit of uniParthenope | Hydrogen Use in maritime sector |
| e-SHyIPS - Ecosystemic knowledge in Standards for Hydrogen Implementation on Passenger Ship | European Clean Hydrogen Partnership | 130.625 (Partenope 35.000) | 2021 - 2024 | uniParthenope Research Unit coordinator | Hydrogen Use in maritime sector & modeling of power unit for ships |
| H2PORTS - Implementing Fuel Cells and Hydrogen Technologies in Ports | European Clean Hydrogen Partnership | 676.900 (Parthenope 75.000) | 2019 - 2024 | uniParthenope Research unit coordinator | First Hydrogen RoRo Tractor in the world |
| Accordo di Programma Ricerca di Sistema – Progetto integrato idrogeno | ENEA – RSE su fondi MASE | 220.000 | 2022-2024 | Member of the Research Unit of uniParthenope | Hydrogen Energy storage Systems |
| HyReFi – Modeling and Optimization of sustainable Hydrogen Refuelling Infrastructure | MUR – Ministero Università e Ricerca – Bando PRIN 2022 PNRR | 165.544 | 2023-2025 | Member of the Research Unit of uniParthenope | Modeling & optimization of Innovative HRS |

ALLEGATO C - Personnel cost



| STANDARD PERSONNEL COST TABLE | | | | PERSONNEL COST |
|---|---|---|---|---|
| **COST RANGE/LEVEL** | **NUMBER OF SUBJECTS** | **HOURLY COST. see note** | **HOURS AMOUNT** | |
| **Low** | **1** | 31 € | 404 | 12.524 € |
| **Medium** | | | | - € |
| **High** | **1** | 73 € | 324 | 23.652 € |
| TOTALS | **2** | | **728** | **36.176 €** |

HOURLY COST: reference should be made to the Interministerial Decree n. 116 of January 24, 2018

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*Legale rappresentante del Proponente o Soggetto capofila*

ALLEGATO C

| PROJECT BUDGET | PERSONNEL COST | OVERHEAD | Costs for Specialist Consulting Services | License costs directly attributable to the project | Costs for materials and equipment directly attributable to the project | Costs for other types of expenses directly attributable to the project | TOTAL COST |
|---|---|---|---|---|---|---|---|
| UNIVERSITA' PARTHENOPE | 36.176,00 € | 5.426,40 € | 90.221,00 € | 0,00 € | 168.176,60 € | | 300.000,00 € |
| Participant 2 | | 0,00 € | | | | | 0,00 € |
| Participant .... | | 0,00 € | | | | | 0,00 € |

*Firma digitale del*
*Legale rappresentante del Proponente o Soggetto capofila*